Comparison of the Aloka 210 and Aloka 500V Ultrasound Machines for Estimation of Body Composition in Beef Cattle

An Honors Thesis

Dawn M. Rayburn

Department of Animal Sciences

The Ohio State University, Columbus, 43210-1095

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Research Advisor: Dr. Michael Davis

Introduction

Analysis of animal body composition using ultrasound machinery has increasingly become a valuable tool for today's conscientious producers. Ultrasound has many benefits in the livestock production sectors of agriculture.

First, ultrasound provides valuable information on animal characteristics that are vital to marketing an animal, such as backfat thickness and loineye area, without having to slaughter the animal. In the past, slaughtering the animal was the only way to obtain these measurements, and if they were not as expected, then nothing could be done to improve the animal. With the use of ultrasound, however, changes can be made to the live animal, for example through nutrition, that may help to produce a more desirable product.

Also, with the use of new ultrasound practices, improvement of carcass traits through genetic selection is a tangible goal (Buckley, 1997). The producer can use the information obtained on each animal to determine whether or not that animal will be used in the producer's breeding program based on carcass traits.

With the increased popularity of ultrasound, the Beef Improvement Federation has begun to examine the accuracy of ultrasound measurements. If ultrasound is to be widely accepted by producers, accurate assessment of animal body composition is key. With the advancement in technology that ultrasounding has seen, newer equipment is much more accurate and reliable than older machines.

In a previous Honors study done by Jeremy Buckley of The Ohio State University, an older machine known as the Aloka 210 was used and found not to be very accurate in determining either backfat or loineye area in live animals. Residual correlations between ultrasound and carcass data were much lower than expected (Buckley, 1997). The objective of this study, therefore, is to compare the accuracy of a newer ultrasound machine, the Aloka 500V, to that of the Aloka 210 studied in Buckley's Honors project. This study will show whether or not technological advances in ultrasound machinery have improved accuracy or whether more advances are necessary.

Literature Review

Ultrasound analysis is not a new concept, and in fact was introduced in 1950 by Wild who stated that the ultrasonic technique is nondestructive and humane and provides a means of quantifying muscle and fatty tissues in live animals (Houghton and Turlington, 1992). Ultrasound was used at that time merely as a means for estimating compositional differences among livestock for sorting purposes. Today, however, ultrasound is used as a source of information for genetic selection, as well as for improving carcass uniformity in feedlot cattle (Basarab et al., 1997).

Early ultrasound machines were very labor intensive, but unfortunately not very accurate. Advances during the late 1970's and early 1980's, however, dramatically improved ultrasound equipment and their accuracy. With the advent of real-time ultrasound (RTU), ultrasounding has become more accurate and easier to interpret (Buckley, 1997).

The machine used in this study, the Aloka 500V, may prove valuable in evaluating carcass merit in beef cattle (Hassen et al., 1998). This evaluation of carcass merit becomes increasingly important as today's livestock industry moves closer to value-based marketing.

The basic concept of ultrasound is to measure an echo rebounding from soft tissues. After the transducer is placed in contact with the animal, the ultrasound equipment transforms electrical pulses to high frequency sound waves. The sound waves then travel into the body and are reflected from boundaries between tissues of different densities. The image that the ultrasound waves transmit through the transducer is projected onto the screen of the ultrasound unit (Houghton and Turlington, 1992). With RTU, echoes are recorded continuously in real time onto a display screen and encoders spatially orient the returning echoes to depict tissue boundaries, which are indicated by varying shades of gray (Buckley, 1997).

Technical improvements in RTU have greatly increased resolution of the ultrasonic image, resulting in improved accuracy. Hassen et al. (1998) reported that accuracy of ultrasound prediction varies with the type of instrument, the skill of technicians collecting and interpreting images, and even the species of livestock used. Research has shown correlations between ultrasound and carcass measurements as high as 0.90 for backfat thickness, and approximately 0.87 for loineye area (Herring et al., 1994).

Caution, however, should be taken when only using correlations to evaluate the accuracy of ultrasound measurements. Limitations of using only correlations include: 1) the fact that population variation influences correlation coefficients, 2) correlation coefficients do not reflect bias, and 3) correlation coefficients are not easily understood by most producer groups (Houghton and Turlington, 1992).

Materials and Methods

General

A total of 325 bulls and heifers were used for this study. The subjects of this study included 81 fall-born calves from 1995, 71 spring-born and 84 fall-born calves from 1996, and 89 spring-born calves from 1997. These calves were purebred Angus cattle and are part of an ongoing study conducted by Dr. M. E. Davis at the Eastern Ohio Resource Development Center (EORDC), Belle Valley, Ohio.

The study conducted by Dr. Davis concerns divergent selection for the hormone insulin-like growth factor I (IGF-I) in blood serum, and its effects on growth and body composition (Davis et al., 1995). Serum IGF-I has been linked phenotypically with weight and growth rate in cattle (Davis et al., 1991) and other livestock species. The IGF-I experiment began in 1989 at the EORDC. This experiment includes approximately 100 spring-calving cows (50 high IGF-I and 50 low IGF-I line cows) and 100 fall-calving (50 high IGF-I and 50 low IGF-I line cows) and their progeny.

Spring-born calves were weaned at approximately 7 months of age, and after a two-week adjustment period, entered a 140-day postweaning test to monitor IGF-I effects on growth and body composition (Davis et al., 1995). The average age of spring-born calves entering the postweaning period was approximately 235 days. Fall-born calves were weaned at approximately 4 ½ months of age and then fed a growing diet for 112 days in dry lot (Davis et al., 1995). These calves then entered the postweaning test period at an average age of 263 days.

Only bulls not needed for breeding were slaughtered. There were 134 bulls used to study the accuracy of ultrasound estimation of carcass traits. Ultrasound data, however, were recorded for all 325 bull and heifer calves.

In this study, the ultrasound equipment used was the Aloka 500V ultrasound machine with a 17 cm 3.5 MHz probe. Only data from fall 1995 to present were analyzed, as from 1990 to 1994 the Aloka 210 machine was used, and in the spring of 1995 an inexperienced technician recorded and interpreted ultrasound images. The Aloka 500V takes one ultrasonic picture of the backfat/loineye area, whereas the machine of comparison in this study, the Aloka 210, obtained two pictures, which had to be aligned to create one picture. Details of the study using the Aloka 210 can be found in the Honors report by Jeremy Buckley. The ultrasound machines and probes were distributed by Corometrics Medical Systems, Wallingsford, CT. The Aloka 210 images were recorded on an 8 mm tape and analyzed using the Animorph ultrasound image interpretation software (Buckley, 1997). The Aloka 500V images were stored directly on the computer for later interpretation.

Ultrasound measurements were taken on day 56 and day 140 of the postweaning period. Ultrasound measurements of backfat at the ¾ point of the longissimus muscle and loineye area were measured between the 12^{th} and 13^{th} rib on all animals. This area was clipped and brushed free of debris and then vegetable oil was applied to the clipped area to create a proper medium for the ultrasonographic images to be of maximal accuracy. The ultrasound transducer was placed laterally over the area and was adjusted until the best image was obtained. The image was frozen on the monitor and then saved on the computer.

Dr. Steve Moeller, an ultrasound technician and a faculty member of The Ohio State University made all ultrasound measurements and interpretations from fall 1995 to the present. Prior to the fall of 1995, ultrasound measurements were taken by the EORDC herdsman, who had minimal training in ultrasounding. Likewise, interpretations of ultrasound images were made by graduate students at The Ohio State University who were not trained in ultrasound interpretation.

At the end of the 140-day postweaning test, bulls not saved for breeding were taken to Falter's Packing Co. in Columbus, Ohio for slaughter. Trained faculty of The Ohio State University Department of Animal Sciences obtained hanging carcass measurements of backfat and loineye area.

Statistical Analysis

Simple means and standard deviations were calculated for carcass and ultrasound backfat thickness and loineye area. This was done to provide a reference point as to the mean values and uniformity of the animals used in this study.

Linear relationships between ultrasound and carcass measurements, as measured by residual correlations, were calculated using the SAS Statistical Software located on the IBM 3090 mainframe computer. The statistical model included fixed effects for year-line-season and age of dam, as well as a covariate for age of calf. A random effect of sire of calf nested within year-line-season was also included.

Residual correlations were obtained between ultrasound measurement of backfat at day 56 (ULTRAFT1) and carcass backfat (FAT), ultrasound measurement of backfat at day 140 (ULTRAFT2) and carcass backfat (FAT), ultrasound measurement of loineye area at day 56 (ULTRALA1) and carcass loineye area (RIBEYE), and ultrasound measurement of loineye area at day 140 (ULTRALA2) and carcass loineye area (RIBEYE). Year and season effects on correlation coefficients were also studied over the period from fall 1995 to spring 1997.

In addition, Spearman rank correlations were calculated to determine whether or not ultrasound ranking of the bulls for backfat thickness and loineye area was similar to carcass ranking of the same animals. Year and season effects on the rank correlations were also considered. Rank correlations were calculated between ULTRAFT1 and FAT, ULTRAFT2 and FAT, ULTRALA1 and RIBEYE, and ULTRALA2 and RIBEYE. Rank correlations between ULTRAFT1 and ULTRAFT2, and between ULTRALA1 and

ULTRALA2 were also calculated to determine whether ultrasound ranking of the bulls was consistent at day 56 and day 140.

Simple correlations, or Pearson product moment correlations, were also calculated using the PROC CORR procedure found in the SAS statistical software program. Simple correlations were correlations between ultrasound measurements and carcass measurements without adjustments for any of the independent variables.

Because use of correlations as measures of accuracy are often criticized due to their dependency on sample variance, root mean square error (RMSE) and error standard deviation (ESD) were also calculated (Houghton and Turlington, 1992). RMSE and ESD are valuable measures of accuracy as they evaluate accuracy independent of variance (Herring et al., 1994). RMSE was calculated by finding the square root of the sum of the squared differences between ultrasound measurements (X_2) and carcass measurements (X_1), divided by the number of animals (n). The formula is as follows:

$$\text{RMSE}= \text{square root } [\Sigma(X_2 - X_1)^2/n]$$

ESD was calculated by finding the square root of the sum of the differences of ultrasound measurement (X_2) minus mean ultrasound measurement (X bar 2) and carcass measurement (X_1) minus mean carcass measurement (X bar 1) squared and then dividing by the number of animals minus 1 (n-1). The formula for calculating ESD is listed below:

$$\text{ESD}= \text{square root } \Sigma\ [(X_2 - \text{X bar 2}) - (X_1 - \text{X bar 1})]^2/n-1$$

As well as providing an indication of accuracy independent of sample variance, ESD data are further adjusted for technician bias as each measurement is deviated from its respective mean (Houghton and Turlington, 1992).

Technician bias was also calculated to determine whether ultrasound estimations were either consistently lower or higher than carcass measurements. Bias was calculated by subtracting the carcass measurements from the ultrasound measurements:

BIASFT1 = ULTRAFT1 - FAT

BIASFT2 = ULTRAFT2 - FAT

BIASLA1 = ULTRALA1 - RIBEYE

BIASLA2 = ULTRALA2 - RIBEYE

Finally, the standard error of prediction (SEP) was calculated to account for technician bias in evaluating the accuracy of ultrasound estimation. SEP is found by taking the square root of the carcass measurements minus the ultrasound measurements minus the average bias and squaring this quantity, and then dividing by the number of animals minus 1 (n-1):

$$\text{SEP} = \text{sqrt}\ (\text{CARCASS VALUE-ULTRASOUND- AVG. BIAS})^2 / \text{n-1}$$

Results and Discussion

Means and standard deviations for FAT, RIBEYE, ULTRAFT1, ULTRAFT2, ULTRALA1, AND ULTRALA2 are found in Table 1. These statistics were obtained in order to characterize the animals used in this study.

Table 1. Simple means and standard deviations for carcass and ultrasound backfat thickness (mm) and loineye area (cm squared)

TRAIT	MEAN	STANDARD DEVIATION
FAT	9.17	3.62
RIBEYE	76.3	8.29
ULTRAFT1	4.67	2.00
ULTRAFT2	8.96	3.65
ULTRALA1	47.0	11.1
ULTRALA2	63.7	15.9

Residual correlations between ultrasound measurements and carcass measurements for all years and seasons combined are listed in Table 2. Residual correlations were much closer to expectations than were those of Buckley's Honors study. When data from all years and seasons were combined, residual correlations were 0.67 between ULTRAFT1 and FAT, and 0.73 between ULTRAFT2 and FAT, as compared with Buckley's values of 0.52 between ULTRAFT1 and FAT, and 0.48 between ULTRAFT2 and FAT.

One possible explanation for the fact that the correlation was higher between ULTRAFT2 and FAT than between ULTRAFT1 and FAT is that ULTRAFT 2 was measured much closer to slaughter than was ULTRAFT 1, and the day 56 ultrasound measurement of backfat was not the measurement that the young animal had when slaughtered after the 140-day performance test.

Likewise, residual correlations involving loineye area were higher than those of Buckley. In this study, the correlations were 0.50 between ULTRALA1 and RIBEYE and 0.60 between ULTRALA2 and RIBEYE, whereas in Buckley's study these values were 0.53 between ULTRALA1 and RIBEYE and 0.33 between ULTRALA2 and RIBEYE.

Loineye area at day 56 is expected to be smaller than loineye area at day 140, thus resulting in a lower correlation with carcass loineye area when loineye area is estimated at day 56. In the case of the day 140 measurements, the fact that with the Aloka 210 two half pictures of the loineye had to be aligned to obtain one estimate of loineye area likely introduced more error. Also, the fact that in spring 1995 and earlier ultrasound images were obtained and interpreted by inexperienced technicians could also have resulted in more error and lower correlation involving the Aloka 210 machine. The fact that loineye correlations were much lower than backfat correlations indicates that backfat is estimated more accurately than is loineye area.

Table 2. Residual correlations between ultrasound data and carcass data for backfat thickness and loineye area at day 56 and day 140 of the postweaning test period

ULTRASOUND TRAIT	CARCASS TRAIT FAT	RIBEYE AREA
ULTRAFT1	0.67	
ULTRAFT2	0.73	
ULTRALA1		0.50
ULTRALA2		0.60

Correlations by year and season are presented in Table 3. Correlations varied between years and seasons, with some years and seasons having exceptionally high correlations and some having lower correlations. Correlations for backfat by year and season ranged from 0.23 for ULTRAFT1 and FAT in the fall of 1995 to 0.93 for ULTRAFT2 and FAT in the spring of 1996. In each year and season, correlations were higher between ULTRAFT2 and FAT than between ULTRAFT1 and FAT, as expected. In Buckley's study, correlations ranged from 0.08 for ULTRAFT2 and FAT to 0.89 for ULTRAFT1 and FAT. These results do not make sense logically, as one would expect higher correlations between ULTRAFT2 and FAT. Correlations involving loineye area by year and season ranged from 0.35 for ULTRALA2 and RIBEYE in the fall of 1995 to 0.65 between ULTRALA1 and RIBEYE in the fall of 1995. Possible sources of variation in this case include misinterpretation of ultrasound images as well as possible errors incurred while recording images. In comparison with Buckley's study, where correlations involving loineye area ranged from -0.61 to 0.78, the correlations from this study were slightly higher.

Table 3. Residual correlations between ultrasound and carcass data for backfat thickness and loineye area at day 56 and day 140 of the performance test by year and season.

	YEAR/SEASON			
	1995	1996		1997
TRAITS	FALL	SPRING	FALL	SPRING
ULTRAFT1:FAT	0.23	0.83	0.53	0.82
ULTRAFT2:FAT	0.43	0.93	0.64	0.88
ULTRALA1:RIBEYE	0.65	0.50	0.65	0.39
ULTRALA2:RIBEYE	0.35	0.61	0.65	0.66

Values for the Pearson product moment correlations between ultrasound measurements and carcass measurements of backfat thickness and loineye area are found in Table 4 over all years and seasons combined and in Table 5 separately by year and season. Correlations were 0.74 and 0.75 for backfat thickness, and 0.60 and 0.65 for loineye area. These simple correlations are similar to the residual correlations presented in Table 2.

When separated by year and season, the results were similar to those found using residual correlations, in that some years and seasons yielded higher correlations than others. The range in correlations for backfat thickness was from 0.25 to 0.87, while the range in correlations for loineye area was from 0.47 to 0.75. Day 56 ultrasound measurements generally yielded lower correlations than did those obtained at day 140.

Table 4. Pearson product moment correlations between ultrasound and carcass measurements of backfat thickness and loineye area over all years and seasons combined

TRAIT	FAT	RIBEYE
ULTRAFT1	0.74	
ULTRAFT2	0.75	
ULTRALA1		0.60
ULTRALA2		0.65

Table 5. Pearson product moment correlations for backfat thickness and loineye area by year and season

	YEAR/SEASON			
	1995	1996		1997
TRAIT	**FALL**	**SPRING**	**FALL**	**SPRING**
ULTRAFT1:FAT	0.25	0.62	0.53	0.82
ULTRAFT2:FAT	0.37	0.80	0.67	0.87
ULTRALA1:RIBEYE	0.74	0.47	0.61	0.56
ULTRALA2:RIBEYE	0.47	0.75	0.66	0.71

Spearman correlations between ultrasound ranking and carcass ranking are presented for all years and seasons combined in Table 6, and separately for each year and season in Table 7. Spearman rank correlations were also high in this study. The correlation between ULTRAFT1 and FAT was 0.66, whereas the correlation between ULTRAFT2 and FAT was 0.71. For loineye area, rank correlations were 0.59 between ULTRALA1 and RIBEYE and 0.64 between ULTRALA2 and RIBEYE. Also, ranking of animals for backfat thickness and loineye area was rather consistent between day 56 and day 140. Rank correlations were 0.72 between ULTRAFT1 and ULTRAFT2, and 0.80 between ULTRALA1 and ULTRALA2. These results indicate that, for the most part, the animals ranked the same at day 56 as at day 140.

Table 6. Spearman rank correlations between ultrasound measurements and carcass measurements of animals based on backfat thickness and loineye area at day 56 and day 140 across all years and seasons

	CARCASS/ULTRASOUND TRAIT			
ULTRASOUND TRAIT	**FAT**	**RIBEYE**	**ULTRAFT2**	**ULTRALA2**
ULTRAFT1	0.66		0.72	
ULTRAFT2	0.71			
ULTRALA1		0.59		0.80
ULTRALA2		0.64		

When data were separated by year and season, similar high rank correlations were obtained in some years and seasons, but in other years and seasons unusually low correlations were observed. Rank correlations ranged from 0.23 for ULTRAFT1 and FAT to 0.84 for ULTRAFT2 and FAT. Correlations ranged from 0.44 for ULTRALA2 and RIBEYE to 0.78 also for ULTRALA2 and RIBEYE. Finally, correlations between ultrasound rankings at day 56 and day 140 ranged from 0.64 to 0.85 for backfat thickness and from 0.75 to 0.90 for loineye area. Possible sources of variation in these rankings include errors in collection and interpretation of images, and again, changes in body composition between day 56 and day 140.

Table 7. Spearman rank correlations between ultrasound ranking and carcass ranking of animals based on backfat thickness and loineye area at day 56 and day 140 by year and season.

	YEAR/SEASON			
	1995	**1996**		**1997**
TRAITS	**FALL**	**SPRING**	**FALL**	**SPRING**
ULTRAFT1:FAT	0.23	0.45	0.49	0.75
ULTRAFT2:FAT	0.42	0.71	0.59	0.84
ULTRALA1:RIBEYE	0.76	0.39	0.54	0.50
ULTRALA2:RIBEYE	0.44	0.78	0.58	0.63
ULTRAFT1:ULTRAFT2	0.64	0.76	0.74	0.85
ULTRALA1:ULTRALA2	0.84	0.90	0.75	0.85

Values for RMSE are presented in Table 8 for all years and seasons combined and in Table 9 separately for each year and season. RMSE values for all years and seasons combined were 4.77 and 2.64 mm for ULTRAFT1 and ULTRAFT2, respectively. Hassen et al. (1998) reported a value of 0.36 cm, which is equivalent to 3.60 mm. Clearly the values obtained in this study were comparable to those of Hassen et al. (1998), and infer that backfat thickness was accurately estimated. RMSE values were 25.13 and 10.16 cm squared for ULTRALA1 and ULTRALA2, respectively.

When calculated by year and season, results similar to Hassen's study were also obtained. For backfat thickness, the range in RMSE was from 1.82 to 5.68 mm, which again is consistent for the most part with Hassen's value of 3.60 mm. Likewise, RMSE for loineye area measurements ranged from 5.80 to 30.12 cm squared. These values are comparable to those obtained by Hassen et al. (1998), which were approximately 12 cm squared.

Table 8. RMSE for backfat thickness (mm) and loineye area (cm squared) for all years and seasons combined.

TRAIT	RMSE
ULTRAFT1	4.77
ULTRAFT2	2.64
ULTRALA1	25.13
ULTRALA2	10.16

Table 9. RMSE for backfat thickness (mm) and loineye area (cm^2) by year and season

	YEAR/SEASON			
	1995	1996		1997
TRAIT	**FALL**	**SPRING**	**FALL**	**SPRING**
ULTRAFT1	5.68	3.28	4.08	5.54
ULTRAFT2	3.24	2.98	2.62	1.82
ULTRALA1	28.8	19.0	30.1	17.6
ULTRALA2	16.6	5.8	8.0	8.8

Values for ESD are presented in Table 10 for all years and seasons combined. Values for ESD were 2.57 and 2.75 mm for ULTRAFT1 and ULTRAFT2, respectively, and 11.58 and 13.90 cm squared for ULTRALA1 and ULTRALA2, respectively. These values are again similar to those obtained in the Hassen et al. (1998) study.

Table 10. ESD for backfat thickness(mm) and loineye area (cm squared) for all years and seasons combined.

TRAIT	ESD
ULTRAFT1	2.57
ULTRAFT2	2.75
ULTRALA1	11.6
ULTRALA2	13.9

Values for technician bias are listed in Table 11. Bias was used to determine if ultrasound measurements were either consistently higher or consistently lower than carcass measurements. Bias was -4.08 mm for backfat at day 56, 1.10 mm for backfat at day 140, -23.4 cm squared for loineye area at day 56, and -2.79 cm squared for loineye area at day 140. Therefore, carcass backfat was slightly overestimated and carcass loineye area was slightly underestimated using the ultrasound machine at day 140. These values demonstrate increased accuracy, or less bias, at day 140 than at day 56, due to the effects of age on body composition.

Table 11. Values for technician bias based on ultrasound measurements for backfat thickness (mm) and loineye area (cm squared) over all years and seasons combined

TRAIT	VALUE
BIASFT1	-4.08
BIASFT2	1.10
BIASLA1	-23.4
BIASLA2	-2.79

Standard error of prediction (SEP) values are shown in Table 12. This calculation accounts for technician bias and shows the error of prediction that occurs without bias, or basically shows accuracy of ultrasound interpretation. The SEP values were low, demonstrating small error of prediction or high accuracy. For backfat thickness, SEP was 0.71 at day 56 and 0.23 at day 140. These values were expected as once again the animal is maturing with age. The SEP values for loineye area, however, were unexpected as the value at day 56 was 0.07 and at day 140 was 0.77.

Table 12. Standard error of prediction (SEP) for backfat thickness (mm) and loineye area (cm squared) over all years and seasons combined

TRAIT	VALUE
SEPFT1	0.71
SEPFT2	0.23
SEPLA1	0.07
SEPLA2	0.77

Backfat thickness and loineye area measurements obtained with the Aloka 500V were much more accurate predictors of carcass measurements than were those obtained with the Aloka 210 machine. Also, values for RMSE and ESD were consistent with those reported in the study of Hassen et al. (1998), which further indicates the accuracy of the Aloka 500V machine. Clearly the introduction of both a trained ultrasound technician and newer equipment have served to greatly increase the accuracy of the ultrasound measurements in the EORDC herd.

Implications

The benefits of an experiment such as this are many fold. One of the foremost benefits is that since the measurements of the Aloka 500V machine are more accurate than those of the Aloka 210, one can now obtain more realistic estimates of the genetic merit of the animals ultrasounded for carcass characteristics. This increased accuracy has valuable implications for producers interested in genetic selection of animals with superior carcass merit.

Another benefit of this more accurate machinery is the economic value of more reliable results. A less accurate machine is not economically sound, in that, a producer is paying for the machine and operator, but is not receiving useful information in return.

Also, when compared with earlier studies in which experienced, trained technicians were not used, one can clearly see the increased accuracy level possible when training in the use of ultrasound equipment is provided. One can conclude, therefore, that trained ultrasound technicians are of utmost importance in obtaining accurate ultrasound measurements.

Results of this study open the door to further study with other equipment to determine whether or not further improvement can be made in the accuracy of ultrasound measurements.

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